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FEDERAL COMMUNICATIONS COMMISSION
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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
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	)	
The Development of Operational,	)	WT Docket No. 96-86
Technical, and Spectrum	)	
Requirements for Meeting	)	
Federal, State and Local Public	)	
Safety Agency Communication	)	
Requirements Through the	)	
Year 2010	)	

To: The Commission

REPLY COMMENTS OF QUANTUM RADIONICS CORPORATION

QUANTUM RADIONICS CORPORATION

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18 December 1996

RESPECTFULLY SUBMITTED,

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COMMENTOR'S QUALIFICATIONS

Quantum Radionics Corporation, hereinafter referred to as QRC, is a high technology engineering research and development firm providing scientific, engineering, technical, and professional support to government and industry. The Executive Vice President and Chief Operating Officer of QRC is Dr. Gregory M. Stone. Dr. Stone holds a Ph.D. in Electrical Engineering, is a member of the Association of Public Safety Communications Officials International (APCO), the Institute of Electrical and Electronics Engineers (IEEE), and, is a Fellow in the Radio Club of America (RCofA).

Dr. Stone has in excess of sixteen years progressive experience in the areas of law enforcement and public safety wireless communications system research, development, and engineering. Current areas of involvement include: 3-dimensional electromagnetic wave propagation modeling and simulation; development of unified wireless communication simulation, modeling, and design methodology applicable to high speed digital wireless systems employing m-ary modulation; linear wireless system architectures; and, cryptographically protected wireless communications systems. He also is engaged in the development and application of advanced electronic crime countermeasure technologies. Dr. Stone has served as a consultant to numerous Federal, state, and local law enforcement, public safety, and governmental agencies, and to such commercial clientele as: IBM; Ameritech; NYNEX; and, GTE.

Dr. Stone currently serves as Chairman of the IEEE VTS-Propagation Committee; as Co-Chairman Telecommunications Industries Association TR-8, WG8.8 Technology Compatibility Committee; and, as a Member of the Executive Committee, IEEE International Carnahan Conference on Security Technology.

All comments contained in this filing are solely those of QRC and do not necessarily represent the opinions or position of any other entity.

EXECUTIVE SUMMARY

In response to the Commission's Notice of Proposed Rulemaking (NPRM), WT Docket 96-86, QRC presents its reply position on matters relating to several of these areas for consideration by the Commission.

Conventional Versus Trunked Public Safety Systems

QRC recommends the Commission not afford any preference to systems employing trunking technology versus those systems employing "conventional", i.e., non-trunked technology.

QRC asserts that spectral efficiency is not equivalent to nor does it mandate the use of trunking technologies.

The fundamental issue to be addressed is that of spectral efficiency which infra, QRC reiterates its recommendations concerning.

What a properly designed trunked system (not employing priority) does provide is an automatic balancing or leveling of user load, which also can be accomplished for far less cost by properly designing, sizing, and implementing a conventional non-trunked system. Thus, the ***only*** difference between a public safety communications system (or any communications system for that matter), employing trunked technology versus non-trunked technology is ***automatic load leveling***.

A trunked system, when priority is not employed, automatically normalizes the offered user load between and amongst the available trunks (channels), whilst in a conventional system load leveling is handled by manually changing channels.

QRC represents that it can be shown deterministically that a properly engineered and load balanced conventional system will have equivalent or better spectral efficiency than a properly designed and operated automatically trunked system.

Therefore, QRC recommends that under NO circumstance should trunked systems be afforded any preferential treatment, but that the Commission instead focus on the issues of spectral efficiency and satisfying public safety operational requirements vis-à-vis additional spectrum allocations

QRC Proposed Measure of Spectral Efficiency

In order to effectively address a baseline quantitative methodology for discerning and comparatively assessing spectrum efficiency, QRC recommends that a concept of Voice Channel Equivalent Erlangs be adopted, whereby the offered load of any type of service (i.e., data, video) have its load normalized to a Voice Channel Equivalent. Thus, spectrum efficiency may be measured by a technology's ability to convey the most Voice Channel Equivalent Erlangs per MHz bandwidth per square kilometer. This approach normalizes load to a Voice Channel Equivalent baseline. This concept is presented in the following expression:

$$E_{vce}/MHz/Km^2$$

SPECIFIC REPLY COMMENTS — PUBLIC SAFETY WIRELESS TECHNOLOGY ISSUES (ITEM 57, PAGE 21)

Conventional Versus Trunked Public Safety Systems

As stated in our initial comments on this NPRM, the Commission's NPRM makes numerous declarative statements concerning the efficacy and alleged benefits of trunking technology that are not correct unless certain very limited factual assumptions are in effect.

The Commission asserts, for example, that trunking technology permits hundreds of users to share a limited number of channels without interference. This is not the case unless the hundreds of users served very rarely use their radio and, when and if they do, it is for very short periods of time. Furthermore, trunked systems never can achieve the capacity, per channel or per trunk, that can be achieved by a non-trunked or conventional system.

In a conventional system each channel or trunk has a capacity of one (1) Erlang. In a trunked system that employs embedded signaling for control, each channel or trunk has a capacity of less than one (1) Erlang due to trunking control overhead.

What a properly designed trunked system (not employing priority) does provide is an automatic balancing or leveling of user load, which also can be accomplished for far less cost by properly designing, sizing, and implementing a conventional non-trunked system.

This brings us to another key point, that is, sizing a system to support the appropriate offered load. QRC asserts that sound traffic engineering principles must be applied in the design of either a conventional or trunked public safety wireless system. In advocating such a position, Dr. Stone developed initially for APCO Project 25 and subsequently submitted to the Public Safety Wireless Advisory Committee (PSWAC) a document entitled: "*Public Safety Wireless Communications User-Traffic Profiles and Grade-Of-Service Recommendations*," dated 13 March 1996. This document was provided as Exhibit-9 to QRC's initial comments to this NPRM.

The PSWAC, in its deliberations, adopted Dr. Stone's traffic profile and grade of service recommendations contained in the subject report. QRC reiterates its recommendations that the Commission now adopt this document as the baseline authority for public safety loading and grade of service.

Public Safety Trunking Viability

Trunking may accrue an advantage only when a public safety trunked communications system is based on an engineering analysis that determines the number of trunks or radio channels needed. This analysis is quantitative and must use either historical or projected voice and/or data traffic information.

A quantitative traffic analysis for designing trunked public safety systems employs telephone trunking queuing theory with appropriate modifications for automatic radio trunking. The quantitative analysis determines the number of radio channels, or *trunks*, required to deliver the desired system performance under known or projected levels of use.

The quantitative traffic analysis predicts the average delay system users are likely to experience during a busy period, given a specific number of channels (trunks). Delay is the time a public safety user must wait before the system offers an open channel. Depending on the communications capability a pubic safety agency requires (for example, little or no delay), traffic engineering will reveal how many channels (trunks) are necessary as compared to how many are available.

How a public safety agency functionally or operationally partitions users and distributes them on different conventional channels helps to determine whether or not automatic trunking is the most effective means of satisfying a public safety agency's communications requirements, independent of the average delay time derived from the quantitative traffic analysis. This introduces the notion of "functional channels".

Functional channels — On a conventional system, a public safety agency might operationally partition users by function on different channels, for example, north and south dispatch, two information channels, one tactical channel, and one supervisory channel. The users may be distributed among different channels in unequal numbers depending upon the operational requirements of the public safety agency.

The functional partitioning of users in a trunked system has a critical impact on how the users accept the system and its ultimate performance. Unless a public safety agency's functional channel partitioning and user load distribution are compatible with trunking limitations, a trunked system exhibits the same, or possibly greater, traffic limitations as dedicated conventional channels.

In addition to the normal delays encountered by users waiting to gain access to a conventional channel, digitally addressed trunking imposes its own technology-induced delays in providing access to a functional channel.

Thus, trunked systems actually offer poorer performance than a conventional system if improper public safety user functional compartmentalization is performed, because there is no benefit accrued from trunking automatic load leveling capability and the trunking overhead has actually diminished available capacity.

In conventional systems, it is common to assign channel labels to a frequency or pair of frequencies with a specific use. The specific use is then assigned to satisfy an agency's operational requirements. It is not a widely accepted alternative to restructure operations based upon limitations of technology, be it trunked or conventional.

On a trunked system, the equivalent of a dedicated conventional channel is a functional channel or "talk-group" or "sub-fleet". Trunking equipment may offer hundreds of sub-fleets or talk-groups, but a public safety agency is unwise to expand its functional divisions, reducing the number of units in each sub-fleet/talk-group, just because trunking makes it possible. It is a mistaken belief that "talk-groups" or "sub-fleets" are equivalent to conventional channels: they are not.

For example, it makes no sense to spread 100 users in the same patrol district over five logical dispatch channels so that traffic passed on "channel one" cannot be heard by units on channels two through five, and vice versa. But for special operations, administrative and supervisory use, and in tactical situations requiring dedicated functional channels, the flexibility afforded by public safety trunking systems may be advantageous.

The most effective way to engineer either a conventional or trunked public safety system is to set the number of functional channels (sub-fleets or talk-groups) to match the number of conventional channels you would otherwise use to meet *operational* requirements.

This requires we address the notion of traffic load distribution on both conventional and trunked systems.

Traffic Load Distribution — Efficient trunking, which provides automatic load leveling and reduces delay, is based on several assumptions. The most important is a uniform traffic loading distribution among functional channels.

If a public safety agency lacks a uniform traffic loading distribution across a public safety agency's functional channels, a public safety agency is better served by a less costly and less complex multichannel conventional system.

Traffic Engineering Considerations

The FCC counts mobile and portable units to determine whether a system is "loaded", but the FCC imposes no requirement regarding delay.

A quantitative traffic analysis reveals how many trunks a public safety agency requires, assuming the load distribution is reasonably equal among the functional channels (sub-fleets or talk-groups), which rarely is the case in public safety operations.

A traffic analysis requires:

- A thorough study of a public safety agency's operational communications needs and requirements.
- Well-defined and attainable articulation of functional operational requirements based on the study.
- A functional channel complement (a decision setting the number of sub-fleets/talk-groups) and user distribution (reasonably equal number of users in each sub-fleet/talk-group).

Grade of Service Considerations

Another important design criterion in the design of public safety communications systems that must be considered to determine how many channels or trunks are needed is the grade of service (GOS).

The ratio of calls not completed on the first attempt at system access, to the total number of attempts to access a channel during a specific period, is the GOS. The specific period chosen for most analyses of public safety systems is the busy hour. It is assumed that attempts fail because all trunks are busy at the time. These calls may be held in a queue which, in some systems, alerts a public safety user when a "channel" becomes available for his/her usage.

An automatically trunked system's traffic capacity is defined as the load that, on the average, provides the GOS chosen as the service objective.

It is important to keep in perspective that if unit loading is distributed so the functional channels (sub-fleets/talk-groups) are overloaded, or if operational procedures are not in place to handle overflow traffic on secondary functional channels (sub-fleets/talk-groups), the system capacity will be less than the traffic analysis predicts.

Extensive use of such features as executive override, priority for certain users, or channel scanning, adversely affects the traffic statistics and increases the number of trunks required to maintain the grade of service. Otherwise, the GOS is degraded to an unacceptable level and the system may prove unusable during emergencies or other periods of heavy use despite an ideal functional channel and user load distribution.

Blocked Call Delay Considerations

The most crucial requirement is that there be no excessive delay in gaining access to the functional channel. Delay is the interval between the moment a public safety user attempts to initiate a transmission and the moment the user actually starts the transmission. Even a modest delay may compromise life and safety.

Consideration of Adverse Factors

Improper functional channel (sub-fleet/talk-group) partitioning and unequal functional channel (sub-fleet/talk-group) distribution already have been identified as two factors that adversely affect the traffic capacity of a trunked system. Two additional factors that have adverse effects are the support of disaster communications and the use or queue and/or service priority.

During disasters, public safety communications traffic changes dramatically. Typically, in times of widespread disaster, public safety radio communications activity increases by a factor of 10 or more, with the duration of messages becoming much longer, increasing to nearly 100 seconds. Under these circumstances, even a properly engineered automatic trunked system could be rendered useless.

An automatic trunking system designed to handle *emergency* communications is incapable of sustaining *disaster* communications unless a disaster operational policy restricts the number of messages and their lengths. The alternatives available to a public safety entity concerned with disaster communications support include:

- Avoid using trunking in the first place (which may be impossible, owing to a lack of conventional channels).

- Build a system with enough trunks to handle disaster communications (which may be impossible, owing to a lack of funds or frequencies or both).

- Have the trunked system revert to a quasi-conventional mode during disasters, allowing automatic load leveling to function, but significantly restricting the potential user pool by restricting access to the system and by limiting the number of functional channels available to be equal to the team size minus the signaling channel. Thus, a ten channel trunked system would be configured to support nine (9) functional channels (sub-fleets/talk-groups).

The Use of Priority in Public Safety Automatic Trunked Communications Systems

Coping with a disaster is not the only problem that may adversely affect trunked system performance. *Priority*, either queuing priority or service priority, may have an adverse effect on automatic trunked system performance.

Many public safety automatic trunked systems offer five levels of user priority. These are:

1. *Emergency priority* is normally activated by an emergency switch. Assuming a trunk is available, emergency priority typically gives direct access to a dispatcher, say within 500 ms. If all trunks are busy, emergency priority permits the first available trunk's user to be pre-empted. It is intended to be used only when immediate communication is necessary to preserve life or safety.

2. *Tactical priority* takes second precedence in the queue when all trunks are busy. Units use it based upon need.

3. *Command priority* is a third level of queue precedence assigned for executive or supervisory uses.

4. *Operational priority* gives a level queue precedence just ahead of routine activities.

5. *Routine priority* takes no precedence.

The use of queue priority involves accepting a significant degree of risk as the feature tends to disturb the exponential arrival process of the users, which is one of the factors used to design the system and to determine the number of trunks needed for a given grade of service. Priority should not be exercised except under unique circumstances. The need should be so great that it offsets the serious disruption and degradation of communications capability that all other non-priority users will suffer.

Furthermore, the fact that a designer equips a system with queue priority implies that the designer believes many, if not most, calls will be blocked and placed in queue. There is no other reason to have queue priority. Thus, it is reasonable to assume that a system designed with queue priority has an undesirably low grade of service, with too many functional channels (sub-fleets) and/or unequal user load distribution, making queue priority necessary to facilitate critical communications.

In addition, it is not only possible, but likely that a public safety agency's operational requirements are such that the functional channel configuration and unit loading distribution result in considerable functional channel congestion, even though the system is operating below its design traffic capacity.

How is this situation addressed? The *only* practical solution to functional channel congestion is to modify the agency's operational requirements and to reallocate functional channels and user distribution.

A second type of priority is service priority. Each user's importance is judged, and trunks are made available on the basis of that importance. In this instance, someone determines which public safety provider, be it a law enforcement agency, emergency medical service, or fire department is on the system and which types of their communications have "higher" priority over the others.

But the presumption once again is that all of the trunks are likely to be busy. Why? Because the system was not designed to handle the required traffic at the appropriate GOS, or the functional channel allocations and user distribution are inappropriate.

It is not unusual to hear the view expressed that, although queuing priority during normal or routine emergency operations may not be necessary, it may be necessary during a disaster. The fact is that technology is not the solution to effective disaster communications. The only sensible and cost-effective way to ensure a survivable disaster communications capability is through a combination of a well-engineered communications system and sound emergency policies and procedures.

A well engineered load balanced conventional system will always out perform an improperly designed overloaded trunked system.

In addition, it can be shown deterministically that a properly engineered and load balanced conventional system will have equivalent or better spectral efficiency than a properly designed and operation automatically trunked system.

QRC PROPOSED METHOD OF SPECTRAL EFFICIENCY

QRC asserts that the Commission adopt a very straightforward yet pragmatic approach to determining the spectrum efficiency of disparate technologies and in the establishment of spectrum efficiency requirements.

QRC recommends that a concept of Voice Channel Equivalent Erlangs be adopted, whereby the offered load of any type of service (i.e., data, video) have its load normalized to a Voice Channel Equivalent.

Thus, spectrum efficiency may be measured by a technology's ability to convey the most Voice Channel Equivalent Erlangs per MHz of bandwidth per square kilometer unit area. This concept is presented in the following expression:

$$E_{vce}/\mathrm{MHz}/\mathrm{Km}^2$$

Note: MHz refers to the bandwidth quantity of spectrum utilized by the subject technology frequently expressed in terms of "authorized bandwidth" such as a 25 or 12.5 kHz channel. This does not refer to the incorrect use of the expression "bandwidth" by the computer industry which refers to information transfer rate in bits per second (b/s) as "bandwidth".

It is important to note that this measure of spectrum efficiency is similar to that proposed by Hatfield and MacDonald, but the QRC approach normalizes load to a Voice Channel Equivalent baseline.